

IRRIGATION PROBE FOR ABLATION DURING OPEN HEART SURGERY

CROSS-REFERENCE TO RELATED APPLICATION(S)

This application is a divisional of U.S. Application Serial No. 09/692,494, filed October 19, 2000, entitled
5 IRRIGATION PROBE FOR ABLATION DURING OPEN HEART SURGERY, which is a continuation-in-part of U.S. Application Serial No. 09/370,601, filed August 10, 1999, the disclosures of which are incorporated herein by reference.

FIELD OF THE INVENTION

10 The present invention is directed to an irrigation ablation probe for use during open heart surgery.

BACKGROUND OF THE INVENTION

Atrial fibrillation is a common sustained cardiac arrhythmia and a major cause of stroke. This condition is
15 perpetuated by reentrant wavelets propagating in an abnormal atrial-tissue substrate. Various approaches have been developed to interrupt wavelets, including surgical or catheter-mediated atriotomy. It is believed that to treat atrial fibrillation by radio-frequency ablation using a
20 catheter, continuous linear lesions must be formed to segment the heart tissue. By segmenting the heart tissue, no electrical activity can be transmitted from one segment to another. Preferably, the segments are made too small to be able to sustain the fibrillatory process.

25 It has been found that over 60% of patients with mitral valve problems also have atrial fibrillation. Moreover, patients undergoing open heart surgery commonly develop atrial fibrillation during the surgery, and thus it would be useful to address this problem during the surgery. Accordingly,
30 under certain circumstances it may be desirable to treat atrial fibrillation during open heart surgery, for example, when a patient is undergoing a mitral valve replacement or

repair procedure. Accordingly, a need exists for devices and methods for treating atrial fibrillation during open heart surgery.

SUMMARY OF THE INVENTION

5 The present invention is directed to an irrigation probe particularly useful for treating atrial fibrillation during open heart surgery. The probe of the present invention is also useful for other ablation and mapping procedures, particularly where irrigation of the ablation site is desired,
10 such as for treating ventricular tachycardia. The invention is also directed to novel methods for treating atrial fibrillation with the probe of the invention. In accordance with the present invention, the probe comprises a rigid probe body and an irrigation electrode, which provides cooling and
15 irrigation in the region of the tissue being ablated.

 In one embodiment, the invention is directed to an irrigation ablation probe comprising a generally rigid probe body having proximal and distal ends. The probe body has an electrode at its distal end defining an inner cavity and
20 having at least one irrigation opening through which fluid can pass and means for introducing fluid into the inner cavity. In a preferred embodiment, an infusion tube having proximal and distal ends is in fluid communication with the inner cavity. In another preferred embodiment, the infusion tube 36
25 extends through the probe body for introducing fluid into the inner cavity of the electrode. In yet another preferred embodiment, the electrode comprises an elongated body having first and second ends, which is fixedly attached, either directly or indirectly, to the distal end of the rigid probe
30 body at a point along the elongated electrode body between its ends, wherein the angle formed between the distal end of the probe body and the electrode is greater than 0°. In still another embodiment, the electrode is attached generally perpendicular to the distal end of the rigid probe body and

has at least three irrigation openings through which fluid can pass. In still yet another preferred embodiment the electrode comprises a flexible metal ribbon coiled around the outside of a looped irrigation tube fixedly attached, either directly or indirectly, to the distal end of the rigid probe body, where the irrigation tube has irrigation openings through which fluid can pass to the electrode and wherein the spaces between the coils provide openings through which fluid can pass to the outside of the irrigation probe.

In another embodiment, the invention is directed to an irrigation ablation probe. The probe comprises a generally rigid probe body as described above and a handle. The handle is mounted to the proximal end of the probe body. In a preferred embodiment, the generally rigid probe body comprises a tubular body, an elongated electrode having first and second ends mounted to the distal end of the rigid probe body at a point along the elongated electrode body between its ends, wherein the angle formed between the distal end of the probe body and the electrode is greater than 0° , and a non-conductive sheath covering the length of the probe body. In still yet another embodiment the electrode comprises a flexible metal ribbon coiled around the outside of a looped irrigation tube fixedly attached either directly or indirectly to the distal end of the rigid probe body, where the irrigation tube has irrigation openings through which fluid can pass to the electrode and wherein the space between the coils provide openings through which fluid can pass to the outside of the irrigation probe.

In another preferred embodiment, the generally rigid probe body comprises tubing having proximal and distal ends and at least one lumen extending therethrough. An electrode as described above is mounted at the distal end of the tubing. The electrode has at least one irrigation opening through which fluid can pass. The probe body further comprises means for introducing fluid through the irrigation opening(s) of the

electrode and a stiffening wire extending through a lumen of the tubing. A preferred means for introducing fluid comprises an infusion tube that extends through a lumen of the tubing with the distal end of the infusion tube in fluid

5 communication with the at least one irrigation opening in the electrode. In one embodiment, an elongated electrode having first and second ends is mounted to the distal end of the rigid probe body at a point along the elongated electrode body between its ends, wherein the angle formed between the distal
10 end of the probe body and the electrode is greater than 0° . In a preferred embodiment the electrode is fixedly attached, either directly or indirectly, generally perpendicular to the rigid probe body and has at least three irrigation openings through which fluid can pass. In another preferred
15 embodiment, the electrode comprises a flexible metal ribbon coiled around the outside of a looped irrigation tube fixedly attached either directly or indirectly to the distal end of the rigid probe body, where the irrigation tube has irrigation openings through which fluid can pass to the electrode and
20 wherein the space between the coils provide opening through which fluid can pass to the outside of the irrigation probe.

In still another embodiment, the invention is directed to a method for treating atrial fibrillation in a patient. The method comprises opening the heart of the patient and ablating
25 at least one linear lesion in the heart tissue using an irrigation probe as described above.

BRIEF DESCRIPTION OF THE DRAWINGS

These and other features and advantages of the present invention will be better understood by reference to the following detailed description when considered in conjunction with the accompanying drawings wherein:

FIG. 1 is a side view of an irrigation probe according to the invention;

FIG. 2 is a side cross-sectional view of the handle of the irrigation probe of FIG. 1;

FIG. 3 is a perspective view of the distal end of the T-shaped irrigation probe of FIG. 1;

FIG. 4 is a side view of an alternative embodiment of an irrigation probe according to the invention;

FIG. 5 is a side cross-sectional view of the distal end of the flexible metal ribbon irrigation probe of FIG. 4, wherein the rigid probe body comprises at least one lumen;

FIG. 6 is an end cross-sectional view of the distal end of the flexible metal ribbon irrigation probe of FIG. 4;

FIG. 7 is a side view of an alternative embodiment of an irrigation probe according to the invention; and

FIG. 8 is a perspective view of the distal end of the flexible metal ribbon irrigation probe of FIG. 7.

DETAILED DESCRIPTION OF THE INVENTION

The present invention is directed to an irrigation probe for use during open heart surgery. In one embodiment, as shown in FIGs. 1 and 2, the irrigation probe **10** comprises a probe body **12** mounted to a handle **14**. the probe body **12** comprises a tubular body **16**, having proximal and distal ends, covered over by a non-conductive covering or sheath **18** along its length and an electrode **19** mounted at the distal end of the tubular body. The electrode **19** is a generally hollow

tubular structure having two ends **20** and defining an inner cavity therein. The electrode **19** is generally perpendicular to the tubular body **16** and fixedly attached to the tubular body **16** at a point between the two ends **20** of the electrode.

5 The junction of the tubular body **16** and the electrode **19** forms an angle α that is greater than 0° , preferably greater than 10° , more preferably greater than 20° , even more preferably ranging from 70° to 110° , still more preferably ranging from 85° to 95° . Still more preferably, the electrode is fixedly
10 attached at an angle α of about 90° relative to the distal end of the probe body, thus forming a generally T-shaped arrangement. The tubular body **16** extends the entire length of the probe body **12**, with the proximal end of the tubular body extending into the handle **14** as described in more detail
15 below. The probe body **12** preferably has a length (from the distal end of the handle to the distal end of the probe body) ranging from about 3.5 inches to about 12 inches, more preferably from about 5 to about 10 inches, still more preferably from about 7 to about 8 inches.

20 The tubular body **16** and the electrode **19** are both made of a material that is generally rigid so that the probe body **12** cannot bend during ablation, such as, for example, stainless steel (preferably 304VSS) or nitinol. Preferably the tubular body **16** and the electrode **19** have an inner diameter ranging
25 from about 0.40 inch to about 0.90 inch, more preferably about 0.047 inch, and an outer diameter ranging from about 0.50 inch to about 0.90 inch, more preferably about 0.059 inch. If desire, the tubular body **16** and/or the electrode **19** can be heat-treated so that they are malleable enough to be bent by a
30 physician to a desired shape but still rigid enough that they will not bend in use during a procedure. For example, for 304VSS stainless steel, the material is heated to about 800°F with electrical current or in a salt bath. The hollow interior of the tubular body **16** forms a lumen through which
35 saline and the like may be conducted to the inner cavity of

the electrode **19** by a separate external tube or the like.

The non-conductive sheath **18** extends from a proximal end inside the handle **14** to a distal end at a union of the tubular body **16** and the electrode **19**. The sheath **18** can be made of
5 any suitable biocompatible non-conductive material, such as polyurethane. In this arrangement, the electrode is exposed, i.e., not covered by the sheath **18**, for ablating tissue, mapping, etc. Preferably, the length of the electrode **19** ranges from about 0.50 inch to about 1.5 inches, more
10 preferably from about 0.75 inch to about 1.25 inches.

In the depicted embodiment, the length of the probe body **12** is approximately 7 inches. The proximal section of the probe body **12**, i.e., the portion extending from the handle **14**, is approximately 5.5 inches. The length of the electrode **19**,
15 is approximately 1 inch.

As shown in detail in FIG. 3, the electrode **19** has a series of irrigation openings **21** for passage of a cooling fluid out through the inner cavity of the electrode **19**. The irrigation openings **21** can take any suitable shape, such as
20 rectangular or oval slots or round holes. In a preferred embodiment the electrode **19** has at least three irrigation openings **21**. the irrigation openings **21** are preferably in the section of the electrode **19** that is to be in contact with the tissue during a procedure, e.g., to enhance the cooling of an
25 ablation site.

Saline or other suitable fluid is introduced into the inner cavity of the electrode **19** through any suitable means. In the embodiment of FIGs. 1 to 3, fluids are introduced into the inner cavity of the electrode **19** via the tubular body **16**
30 through a luer hub **22** or the like at the proximal end of the probe **10**. The luer hub **22** is connected to a flexible plastic tubing **24**, e.g., made of polyimide. The plastic tubing **24** is attached, either directly or indirectly, to the proximal end of the tubular body **16**, preferably within the handle **14**, as
35 shown in FIG. 2. Alternatively, the tubing **24** can be

connected to a suction source (not shown) to permit aspiration of fluid from the region of tissue being operated on.

As shown in FIG. 2, the handle **14** comprises a housing **26** having a generally open interior **28**. the tubular body **16** and sheath **18** extend into the distal end of the handle housing **26**. In the depicted embodiment, the sheath **18** terminated a short distance proximal to the distal end of the housing **26**. the tubular body **16** continues proximally beyond the sheath **18**. The flexible plastic tubing **24** extends into the proximal end of the handle housing **26**. The plastic tubing **24** is attached to the tubular body **16** within the open interior **28** of the handle, preferably at a point proximal to the proximal end of the sheath **18**. The plastic tubing **24** can be attached to the tubular body **16** by any suitable means, for example, polyurethane glue. By this design, cooling fluid is introduced through the luer hub **22**, thorough the plastic tubing **24**, through the tubular body **16** and out the irrigation opening **21** in the electrode **19**.

Alternatively, fluid could be supplied to the electrode **19** and thereby the irrigation openings **21** via a separate irrigation tube (not shown) that can either run external to the tubular body **16** and attach directly to the electrode **19**, or can extend through the tubular body **16** to the electrode **19**. In either case, this separate irrigation tube could be made of any suitable material, e.g., plastic or metal, and attach to the electrode **19** by any direct or indirect means.

An electrode lead wire **30** having proximal and distal ends is electrically connected at or adjacent its distal end to the probe body **16**. The proximal end of the lead wire **30** is attached to a connector **32** for connection to a suitable source of ablation energy, e.g., radio-frequency energy, or to an appropriate monitor. In the depicted embodiment, the lead wire **30** extends into the proximal end of the handle housing **26**. Within the open interior **28** of the handle **14**, the distal end of the lead wire **30** is wrapped around the portion of the

tubular body **16** not covered by the sheath **18** and held in place by solder or the like. The portion of the lead wire **30** that extends outside the handle **14** is covered by a flexible plastic protective tubing **34**, e.g., made of polyimide.

5 An alternative embodiment of an irrigation probe according to the invention is shown in FIGs. 4 to 6. As shown in FIG. 4, the probe **10** comprises a probe body **12** and a handle **14**. The probe body **12** comprises a non-conductive tubing **40** having proximal and distal ends. In a particularly preferred
10 embodiment, the non-conductive tubing **40** comprises outer and inner plastic walls, e.g., of polyurethane or polyimide, surrounding an imbedded braided mesh of stainless steel or the like. Preferably the tubing has an outer diameter or less than 8 French, more preferably less than 7 French. The tubing
15 **40** has three lumens **42**, **44** and **46** extending along its length.

 The irrigation probe comprises a metal ribbon electrode **47** at the distal end **48** of the non-conducting tube **40** comprising an exposed metallic ribbon **49** that is coiled around a loop of irrigation tubing **56**, both of which are indirectly
20 or directly fixedly attached to the distal end **48** of the non-conducting tube **40**. as illustrated in FIG. 5, the probe's distal end **48** is generally solid, having a fluid passage **50**, a first blind hole (not shown) and a second blind hole **54** that correspond in size and location to the three lumens **46**, **42**,
25 and **44**, respectively, in the non-conductive tubing **40**. In the embodiment shown, the fluid passage **50** is in fluid communication with the inner cavity of the flexible irrigation tube **56**, which extends from the distal end of the fluid carrying lumen **46** out of the probes distal end **48**. The
30 irrigation tube **56** has a series of irrigation openings **57** for passage of a cooling fluid out through the spaces between the coils of the metallic ribbon **49**, as described in more detail below. The irrigation openings **57** can take any suitable shape such as rectangular or oval slots or round holes. In a
35 preferred embodiment, the irrigation tubing **56** has at least

three irrigation openings 57. The irrigation openings 57 are preferably in the section of the irrigation tubing 56 corresponding to the section of the metal ribbon electrode 47 that is to be in contact with the tissue during an ablation procedure to enhance the cooling to the ablation site.

The metallic ribbon 49 is coiled loosely around the irrigation tube 56 such that fluid can pass unimpeded to the outside of the metal ribbon electrode 47. the metal ribbon electrode 47, as shown in detail in Fig. 5, comprises a continuous ribbon 49 or conducting metal, extending outside of the probe's distal end 48 and coiled about the flexible irrigation tube 56 in a loop, having a radius ranging from about 0.5 inch to 1.5 inches. The metal ribbon 49 can be coiled in any manner wherein the coils of the metal ribbon define an inner tubular passage through which the irrigation tube 56 runs and wherein the coils of metal ribbon 49 are generally spaced sufficiently far apart to allow fluid to escape through the irrigation passages. In a preferred embodiment, the metal ribbon electrode 49 is coiled around from 1% to 100% of the length of the irrigation tube 56 that is outside the probe body 12. More preferably, the metal ribbon 49 is coiled around from 20% to 80% of the length of the irrigation tube 56, still more preferably the metal ribbon is coiled around from 40% to 60% of the length of the irrigation tube 56. the metal ribbon 49 can be made of any suitable material, and is preferably machined from a 0.005 inch thick ribbon of nitinol.

The metal ribbon 49 and the irrigation tube 56 can be attached to the probe's distal end 48 in any suitable manner. In the depicted embodiment, the metal ribbon 49 and the irrigation tube 56 are each attached at both ends to the probe's distal end 48 by a polyurethane glue seal 58 or the like. However, any other means for fixedly mounting the metal ribbon 49 and the irrigation tube 56 on the probe's distal end 48 can also be used. For example, only one end of the metal

ribbon 49 and/or the irrigation tube 56 may be attached to the probe's distal end 48.

The metal ribbon electrode 47 is connected to a lead wire 67 having proximal and distal ends. The proximal end of the lead wire 67 for the metal ribbon electrode 47 extends through the third lumen 46 of tubing 40 and through the handle 14. The distal end of the lead wire 67 for the metal ribbon electrode 47 extends through the third lumen 46 and is attached to the metal ribbon electrode 47 by any conventional technique, for example, by soldering.

In the embodiment shown, a mapping ring electrode 62 is mounted on the tubing 40 proximal to the probe's distal end 48. It is understood that the presence and number of ring electrodes may vary as desired. The ring electrode 62 is slid over the tubing 40 and fixed in place by glue or the like. The ring electrode 62 can be made of any suitable material, and is preferably machined from platinum-iridium bar (90% platinum/10% iridium).

The ring electrode 62 is connected to a lead wire 64 having proximal and distal ends. The proximal end of the lead wire 64 for the ring electrode 62 extends through the first lumen 42 of tubing 40 and through the handle 14. The lead wire 64 can be connected to the ring electrode 62 by any conventional technique. Connection of the lead wire 64 to the ring electrode 62 is preferably accomplished by first making a small hole through the tubing 40. Such a hole can be created, for example, by inserting a needle through the tubing 40 and heating the needle sufficiently to form a permanent hole. The lead wire 64 is then drawn through the hole using a microhook or the like. The ends of the ring electrode lead wire 64 are then stripped of any coating and soldered or welded to the underside of the ring electrode 62, which is then slid into position over the hole and fixed in place with polyurethane glue or the like. Any other means for fixedly mounting the ring electrode 62 to the tubing 40 can also be used.

Both lead wires **64** and **67** terminate at their proximal end in a connector **32** that may be plugged into an appropriate monitor and/or source of radio-frequency or other ablation energy. The portion of the lead wires **64** and **67** extending out
5 the proximal end of the handle **14** are enclosed within a protective tubing **34**, which can be made of any suitable material, preferably polyimide, as shown in FIG. 4.

An infusion tube **72** is provided for infusing fluids, e.g., saline, to cool the metal ribbon electrode **47** during
10 ablation. the infusion tube **72** may also be used to infuse drugs to the ablation site. The infusion tube **72** may be made of any suitable material, and is preferably made of polyimide tubing. The infusion tube **72** has proximal and distal ends, with its distal end mounted in the fluid passage **50** of the
15 probe's distal end **48** by any suitable method, e.g., by polyurethane glue or the like. The infusion tube **72** extends from the probe's distal end **48**, through the third lumen **46** of the tubing **40**, and through the handle **14**. as would be recognized by one skilled in the art, the distal end of the
20 infusion tube **72** can be positioned at any point within the third lumen **46**. the proximal end of the infusion tube **72** ends in a luer hub **22** or the like. Any other means for infusing fluids to the metal ribbon electrode **47** can also be used, including running the infusion tube **72** external to the tubing
25 **40** and fluid passage **50**.

A stiffening wire **74**, having proximal and distal ends, is mounted in the second lumen **44** of the tubing **40**. the stiffening wire **74** is made of a rigid metal or plastic material, preferably stainless steel, to prevent the probe
30 body **12** from bending during a procedure. If desired, the stiffening wire **74** can be heat-treated so that it is malleable and can be bent to a desired shape before use, but still rigid enough that it will not bend in use during a procedure. A non-conductive tube **76**, preferably made of polyimide, is
35 attached to the distal end of the stiffening wire **74** for

mounting the stiffening wire in the probe's distal end **48**.
the non-conductive tube **76** extends out of the second lumen **44**
and into the second blind hole **54** in the probe's distal end
48, and is secured in place by polyurethane glue or the like.

5 Any other means for securing the stiffening wire **74** within the
probe can also be used. The proximal end of the stiffening
wire **74** terminates in the handle **14** or near the proximal end
of the probe body **12**.

While FIGs. 4 to 6 depict an irrigation probe **10** having a
10 metal ribbon electrode **47**, it will be understood that the
irrigation probe **10** described above and illustrated in FIGs. 4
to 6 could also house the generally T-shaped electrode **19**
illustrated in FIGs. 1 to 3. In this embodiment the generally
T-shaped electrode **19** is fixedly attached, either directly or
15 indirectly, to the probe's distal end **48** such that the fluid
passage **50** is in fluid communication with the inner cavity of
the generally T-shaped electrode **19**. The construction and
function of the lumens **42**, **44** and **46**, and the remainder of the
probe **10** would be similar to that described above and shown in
20 FIGs. 4 to 6.

In another embodiment, as shown in FIGs. 7 and 8, the
irrigation probe **10** comprises a probe body **12** mounted to a
handle **14**, which is described in detail above. The probe body
12 comprises a tubular body **16**, having proximal and distal
25 ends, covered over by a non-conductive covering or sheath **18**.
In this embodiment, a metal ribbon electrode **35** comprising a
coiled metal ribbon **33** and a loop of flexible irrigation tube
36 is disposed at the distal end of the probe body **12** and
fixedly attached, either directly or indirectly, to the distal
30 end of the tubular body **16**. The probe body **12** preferably has
a length (from the distal end of the handle to the distal end
of the probe body) ranging from about 3.5 inches to about 12
inches, more preferably from about 5 inches to about 10
inches, still more preferably from about 7 inches to about 8
35 inches.

The tubular body **16** is made of a material that is generally rigid so that the probe body **12** cannot bend during ablation, such as , for example, stainless steel (preferably 304VSS) or nitinol. Preferably the tubular body **16** has an
5 inner diameter ranging from about 0.40 inch to about 0.80 inch, more preferably about 0.047 inch, and an outer diameter ranging from about 0.50 inch to about 0.90 inch, more preferably about 0.059 inch. If desired, the tubular body **16** can be heat-treated so that it is malleable enough to be bent
10 by a physician to a desired shape but still rigid enough that it will not bend in use during an ablation procedure. The hollow interior of the tubular body **16** forms a lumen through which saline and the like may be conducted to the irrigation tube **36** of the metal ribbon electrode **35** and from there
15 infused during an ablation procedure, as described in more detail below. Alternatively, the tubular body **16** could be solid, in which case fluids could be introduced into the irrigation tube **36** via a separate external tube or the like.

The non-conductive sheath **18** extends from the proximal
20 ends of the tubular body **16** inside the handle **14** to the distal end of the tubular body at the union of the tubular body **16** and the metal ribbon electrode **35**. The sheath **18** can be made of any suitable biocompatible non-conductive material, such as polyurethane. Preferably the diameter of the loop f the metal
25 ribbon electrode **35** ranges from about 0.50 inch to 1.5 inches, more preferably from about 0.75 inch to about 1.25 inches.

In the depicted embodiment, the length of the probe body **12** is approximately 7 inches. The proximal section of the probe body **12**, i.e., the portion extending from the handle **14**,
30 is approximately 5.5 inches. The diameter of the loop of the metal ribbon electrode **35** is approximately 1 inch.

As shown in detail in FIG. 8, the metal ribbon electrode **35** comprise an irrigation tube **36** having first and second ends **37**, at least on e of which is fixedly attached either directly
35 or indirectly to the tubular body **16**, similar to the

embodiment depicted in FIGs. 4 to 6. the irrigation tube **36** is bent so as to form a loop and the metal ribbon **33** is in turn coiled around the irrigation tube **36** and fixedly attached, either directly or indirectly, to the tubular body **16**. In one preferred embodiment, the metal ribbon **33** and irrigation tube **36** are both attached to the tubular body **16** at both ends by any direct or indirect means, e.g., via a glue seal **38** as shown above in FIG. 5. Any other means for attaching the metal ribbon **33** and the irrigation tube **36** can also be used.

As shown, the irrigation tube **36** has a series of irrigation openings **39** for passage of a cooling fluid out through the metal ribbon **33**. the irrigation openings **39** can take any suitable shape, such as rectangular or oval slots or round holes. In a preferred embodiment, shown in FIG. 8, the irrigation tube **36** has at least three irrigation openings **39**. the irrigation openings **39** are preferably in the section of the irrigation tube **36** corresponding to the section of the metal ribbon **33** that is to be in contact with the tissue during a procedure, e.g., to enhance the cooling of the ablation site. The metal ribbon **33** is coiled loosely around the irrigation tube **36** such that fluid can pass unimpeded through the metal ribbon **33**.

Saline or other suitable fluid is introduced into the tubular body **16** through a luer hub **22** or the like at the proximal end of the probe **10**. the luer hub **22** is connected to a flexible plastic tubing **24**, e.g., made of polyimide. The plastic tubing **24** is attached, either directly or indirectly, to the proximal end of the tubular body **16**, preferably within the handle **14**, as shown in FIG 7. By this design, cooling fluid is introduced through the luer hub **22**, through the plastic tubing **24**, through the tubular body **16**, through the first and second ends **37** of the irrigation tube **36** and out the irrigation openings **39**.

The irrigation probe shown in various embodiments in

FIGs. 1 to 8, having either a metal ribbon electrode or a generally T-shaped electrode, can be used in any manner in which a standard probe can be used. For example, the above described probes can be used during open heart surgery for ablation. During an ablation procedure, the heart is opened and the irrigated electrode is used to form continuous linear lesions by ablation. As used herein, a linear lesion refers to any lesion, whether curved or straight, between two anatomical structures in the heart that is sufficient to block a wavelet, i.e., forms a boundary for the wavelet. Anatomical structures, referred to as "atrial trigger spots," are those regions in the heart having limited or no electrical conductivity and are described in Haissaguerre et al., "Spontaneous Initiation of Atrial Fibrillation by Ectopic Beats Originating in the Pulmonary Veins," New England Journal of Medicine, 339:659-666 (Sept. 3, 1998), the disclosure of which is incorporated herein by reference. The linear lesions typically have a length of from about 1 cm to about 4 cm, but can be longer or shorter as necessary for a particular procedure.

The probe described in FIGs. 1 to 3 having a long tubular electrode is particularly useful for this procedure because it can create relatively long lesions. The probe depicted in FIGs. 4 to 6 above, having a smaller but flexible ablation electrode, is useful if the surgeon does not want to ablate as much tissue or wants to ablate a more precise lesion. The above-described probe having a flexible body is particularly useful if the surgeon needs to have a probe that conforms to a particular site to better ablate a desired region of tissue. Additionally, the flexible electrode is particularly useful for ablating locations where it is desirable to have the electrode conform to the tissue, rather than having the tissue conform to the electrode, for example, an atrial appendage. Further, the circular coil design can be used to form a generally circular region around an orifice of a

tubular structure, such as a pulmonary vein, the coronary sinus, the superior vena cava, or the inferior vena cava. Once the heart is closed, the surgeon can use the probe on the outside of the heart, not only to ablate, but to verify that the electrical conduction has been stopped using the mapping electrodes. As would be recognized by one skilled in the art, the probes of the present invention can be used during open heart surgery for other procedures as well.

The preceding description has been presented with reference to presently preferred embodiments of the invention. Workers skilled in the art and technology to which this invention pertains will appreciate that alterations and changes in the described structure may be practiced without meaningfully departing from the principal, spirit and scope of this invention.

Accordingly, the foregoing description should not be read as pertaining only to the precise structures described and illustrated in the accompanying drawings, but rather should be read consistent with and as support for the following claims which are to have their fullest and fairest scope.